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ZERO LOWER BOUND, UNCONVENTIONAL MONETARY POLICY AND INDICATOR PROPERTIES OF INTEREST RATE SPREADS

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Zero lower bound, unconventional monetary policy and indicator properties of interest rate spreads*

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Abstract

This paper re-examines the out-of-sample predictive power of interest rate spreads when the short-term nominal rates have been stuck at the zero lower bound and the Fed has used unconventional monetary policy. Our results suggest that the predictive power of some interest rate spreads have changed since the beginning of this period. In particular, the term spread has been a useful leading indicator since December 2008, but not before that. Credit spreads generally perform poorly in the zero lower bound and unconventional monetary policy period. However, the mortgage spread has been a robust predictor of economic activity over the 2003–2014 period.

Keywords: business fluctuations, forecasting, interest rate spreads, monetary policy, zero lower bound, real-time data

JEL codes: C53, E32, E44, E52, E58

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1. Introduction

The empirical literature focusing on forecasting U.S. real macroeconomic variables has found that interest rate spreads have substantial predictive power for future economic activity. In particular, the term spread, i.e., the difference between the yields on long-term and short-term Treasury securities, has been identified as one of the most informative leading indicators (see, e.g., Stock and Watson, 2003). The term spread has predictive power because it is an indicator of the stance of monetary policy, which is an important driver of business cycles. The relationship between the term spread and future output growth is positive, i.e., higher spread indicates higher future growth.

The previous literature has also documented that various credit spreads contain significant information about subsequent real activity (see, e.g., Bernanke, 1990; Bernanke and Blinder, 1992; Friedman and Kuttner, 1992, 1998; Gertler and Lown, 1999; Mody and Taylor, 2003; Gilchrist *et al.*, 2009; Gilchrist and Zakrajšek, 2012; Faust *et al.*, 2013). Credit spread means either the difference between the yields on various corporate bonds and government bonds of comparable maturity or the difference between the yields on two private debt instruments differing with respect to their rating categories. Credit spreads are informative about future activity because they are indicators of changes in the supply of credit and market participants' expectations of default. They are also, at least to some extent, indicators of an effective monetary policy because the central bank's actions affect the supply of credit and the likelihood of defaults.

The predictive power of interest rate spreads varies over time. For example, it is a well-known fact that the ability of the term spread to forecast future economic activity has diminished since the mid-1980s (Stock and Watson, 2003 and the references cited therein). The changes in the predictive content of the term spread often correspond closely to major changes in the conduct of monetary policy (Estrella *et al.*, 2003; Giacomini and Rossi, 2006; Bordo and Haubrich, 2008). Therefore, regime shifts in monetary policy are potentially important for the predictive power of the term spread. Similarly, because credit spreads are, at least to some extent, indicators of the stance of monetary policy, changes in monetary policy may also affect their predictive ability.

The financial crisis in 2008 changed the Fed's monetary policy altogether. Prior to the crisis the federal funds rate – the Fed's traditional monetary policy instrument – was well above zero. Since December 2008, the federal funds rate has been essentially stuck at the zero lower bound (ZLB). Figure 1 demonstrates this fundamental change in monetary policy by plotting ten-year and one-year Treasury rates and the federal funds rate from 2000 through 2014. Although the federal funds rate has been at the lower bound of zero[1], the recovery from the crisis has been slow. Therefore, the Fed has started to use unconventional monetary policies. The Fed has launched asset purchase programs, often referred to as quantitative easing, and used forward guidance. The aim of these two unconventional policies is to lower long-term rates and hence boost economic activity.

The fundamental change in monetary policy since December 2008 is potentially important for the predictive power of interest rate spreads for several reasons. First, in the non-ZLB environment, the term spread correlates negatively with the short-term rate and is uncorrelated with the long-term rate (see Table 2). In contrast, when the short-term rate is fixed at or near zero, the term spread fluctuates essentially one-for-one with the long-term rate. Second, related to the first reason, the possible values of the term spread are restricted when the short-term rate is fixed at the ZLB. In the non-ZLB period, when both the short-term and long-term rates fluctuate, the term spread can be negative, zero, or positive. When the short-term rate is fixed at or near zero, the term spread equals the long-term rate and can thus have only non-negative values. Third, as discussed in Krippner (2013), the term spread is a directionally misleading measure of the stance of monetary policy in ZLB/unconventional monetary policy

[1]Investors always have the option of holding cash, so interest rates cannot be reduced below zero.

environments. Tight monetary policy periods in non-ZLB/conventional monetary policy environments have corresponded with low values of the term spread. However, in the ZLB/unconventional monetary policy environment since December 2008, the term spread decreases because the long-term rate falls while the short-term rate remains essentially fixed at the zero level. Hence, the decreasing spread could be misinterpreted as a tightening of monetary policy when actually the use of unconventional methods substantially eases monetary policy. Fourth, the long-term rate depends on the entire path of expected future short-term rates. Hence, if the short-term rates are assumed to be at the zero level for a sufficiently long period, the ZLB constraint on short-term rates should also affect the behavior of the long-term rates. However, Swanson and Williams (2014) find that, for instance, the ten-year Treasury rate was essentially unconstrained by the zero bound throughout 2008-2010. Since late 2011, the sensitivity of the ten-year Treasury rate to macroeconomic news has fallen, indicating that the long-term rate has been affected by the ZLB.[2] This finding suggests that the predictive ability of interest rate spreads depending on the long-term Treasury rate might have changed since the onset of the ZLB/unconventional monetary policy period.

The short-term rates in the U.S. have been effectively constrained by the ZLB only in the 1930s and since 2008. Although very low interest rates have been rare, Bernanke *et al.* (2004) and Chung *et al.* (2012) argue that the ZLB restriction is nowadays much more likely to become binding than in the past. The primary reason for this is the change in the way central banks conduct monetary policy. Modern central banks have adopted an inflation target and are thus committed to keeping inflation at a low level. Low and less volatile inflation has in turn allowed for lower interest rates. Low inflation and interest rates increase the probability that negative shocks will force the central bank to lower the short-term rate to the ZLB. As a consequence, we believe that

[2]Swanson and Williams (2014) offer two explanations for their findings. Until late 2011, market participants expected that the Fed would raise the short-term rate from zero within a few quarters, which minimized the effect of the ZLB on long-term Treasury rates. On the other hand, the unconventional monetary policy actions have helped offset the effects of the ZLB on long-term rates.

empirical study of the leading indicator properties of interest rate spreads when the ZLB restriction is binding is highly worthwhile.

In this paper, we examine whether the ZLB and unconventional monetary policy has affected the real-time out-of-sample predictive power of the term spread and a set of credit spreads for U.S. industrial production. The main finding from this study is that the predictive content of the term spread has changed since the beginning of the ZLB/unconventional monetary policy period. We find that the term spread does not contain predictive power for future economic activity in non-ZLB/conventional monetary policy environments. However, the term spread is a useful leading indicator in the ZLB/unconventional monetary policy period. Thus, our results support the view that changes in monetary policy affect the predictive ability of the term spread (see Estrella, 2005). The results also indicate that the mortgage spread (i.e., the difference between the 30-year mortgage rate and ten-year Treasury bond rate) is a particularly informative leading indicator. It is a robust predictor of industrial production growth across a variety of sample periods and forecast horizons. The mortgage spread systematically contains predictive power in our real-time forecasting exercise both in the non-ZLB/conventional monetary policy and ZLB/unconventional monetary policy periods.

The remainder of the paper is organized as follows. In Section 2, we describe the econometric methodologies. Section 3 presents the empirical results, and Section 4 contains concluding remarks.

2. Methodology

In this section, we briefly describe the econometric methodologies used in this paper. The purpose of this study is to examine whether different spreads forecast future economic activity in the ZLB/unconventional monetary policy period.[3] In order to analyze this question, we follow Stock and Watson (2003), Rossi (2013), and Ng and Wright (2013) and estimate the following linear, horizon-specific h-step ahead regression model:

$$Y_{t+h}^{h} = \beta_0 + \sum_{i=0}^{p} \beta_{1i} X_{t-3i} + \sum_{j=0}^{q} \beta_{2j} Y_{t-j} + u_{t+h}^{h}, \qquad t = 1, ..., T \tag{1}$$

where the dependent variable and the lagged dependent variable are

$Y_{t+h}^{h} = (1200/h)ln(IP_{t+h}/IP_t)$ and $Y_{t-j} = 400ln(IP_{t-3j-1}/IP_{t-3j-4})$, respectively, IP_t is the industrial production at month t[4], X_t is the candidate predictor, and u_{t+h}^{h} is an error term.[5] The forecast horizon h is chosen such that we forecast economic activity one, two, three, and four quarters ahead (i.e., h = 3,6,9,12). The forecasting regression (1) is estimated by OLS.

We evaluate the forecasting performance of various interest rate spreads using a real-time out-of-sample forecasting exercise. We follow the procedure proposed by Stock and Watson (2003) and allow the lags of Y_t to vary between zero and four and the lags of X_t to vary between one and four in the forecasting model (1) (so we have 20 different models for each interest rate spread). At each forecast origin, the model with the lowest Bayesian information criteria (BIC) is chosen. Unlike Stock and Watson (2003), we use a rolling estimation scheme. This estimation scheme is more appropriate for our

[3]Monthly industrial production is used to gauge the state of the economy. The most frequently used measure of economic activity in the previous literature is the quarterly GDP. In our case, the number of observations is important because the ZLB/unconventional monetary policy period is relatively short (running from December 2008 to March 2014). Therefore, monthly industrial production is more appropriate for our purposes.

[4]The one month publication lag in the industrial production series is taken into account. We use quarterly lags instead of monthly lags because we want to include information from the latest year to the forecasting regression and still keep the model relatively parsimonious.

[5]Alternatively, we could use univariate regression equations including only current and lagged values of the candidate predictor as regressors. However, this approach has an important shortcoming: the industrial production series is serially correlated and thus its own past values are themselves useful predictors. By including the lagged values of the dependent variable, we consider the marginal predictive power of the spreads, i.e., whether they have predictive content for Y_{t+h}^{h} when its own past values Y_t are already taken into account.

purposes than a recursive scheme for two reasons. First, as Giacomini and White (2006) point out, when the forecasting model is misspecified, it is often the case that a limited memory estimator provides more reliable forecasts than an expanding window estimator. Second, tests of equal predictive ability (discussed below) require limited memory estimators and thus rule out the recursive estimation scheme.

A standard way to quantify out-of-sample forecast performance is to compute the mean squared forecast error (MSFE) of a candidate forecast relative to a benchmark. Because the growth rate of industrial production is serially correlated and thus its own past values are themselves informative about future industrial production growth, it is natural to use an autoregressive (AR) model as a benchmark. The results from the literature indicate that it is relatively hard to outperform the AR benchmark (see, e.g., Stock and Watson, 2003; Elliott and Timmermann, 2008; Rossi, 2013). For the benchmark model, we consider lags between one and four and again choose the optimal lag length at each forecast origin with the BIC. If the relative MSFE is less than one, the model with the spread has produced more accurate forecasts than the AR benchmark. This implies that the spread contains marginal predictive power. However, the difference in the predictive content might not be statistically significant. The relative MSFE could be less than one simply because of sampling variability. Thus, we need more formal test procedures for deciding which spreads contain predictive power.

In our setting, forecast evaluation is complicated by the fact that both the model using the spread and the benchmark model have a recursive BIC lag length selection. This implies that we might possibly use both nested and non-nested models when generating a sequence of out-of-sample forecasts. The Giacomini and White (2006) test of equal conditional predictive ability and test of equal unconditional predictive ability allow the comparison of both nested and non-nested models as well as models that change from time to time and are thus appropriate for our purposes.

The test of equal unconditional predictive ability tests the null hypothesis that the two forecasting methods are equally accurate on average over the out-of-sample period. Rejection of the null hypothesis implies that one of the two methods produces on average more accurate forecasts than the other method. On the other hand, the test of equal conditional predictive ability examines whether some available information (above and beyond past average behavior) can be used to predict which forecast will be more accurate for a specified future date. Under the null hypothesis the two methods are equally accurate and thus one cannot predict which method will be more accurate using the information in the conditioning set. Rejection of the null hypothesis indicates that the conditioning information (e.g., some feature of the economy) can be used to decide which forecasting method is preferable at each forecast origin. Because we are interested in analyzing whether the ZLB and unconventional monetary policy change the predictive ability of different spreads, we condition the relative predictive ability on an indicator taking the value of one when the ZLB restriction is binding and zero otherwise.[6] In our case, the null hypothesis states that the forecasting model using the spread and the AR benchmark have equal predictive ability regardless of whether the short-term rate is at the ZLB or not.

Giacomini and Rossi (2010) point out that the relative forecasting performance may change over time in unstable environments. In such a case, average relative performance over the whole out-of-sample period may hide important information and even lead to incorrect conclusions. We analyze time variations in the relative forecasting performance using methods developed by Giacomini and Rossi (2010). Their fluctuation test is simply the Giacomini and White (2006) test of equal unconditional predictive ability computed over a rolling out-of-sample window size of m. This fluctuation test examines whether the local relative forecasting performance of the methods is equal at each point in time. Under the null hypothesis the two methods yield equally accurate forecasts at each point in time. If the null hypothesis is rejected, one of the

[6]In other words, we use the test function $h_t = (1, ZLB_t)'$, where ZLB_t is a dummy variable that takes a value of one when the ZLB restriction is binding (2008:M12—2014:M3) and zero otherwise.

methods outperformed its competitor at some point in time.

3. Empirical results

This section describes the data and summarizes our empirical results. The sample period runs from 1987:M9 to 2014:M3. Different vintages of an industrial production series used in an out-of-sample forecasting exercise were obtained from the Philadelphia Fed's real-time database. The monthly interest rate data were obtained from the St. Louis Fed's FRED database.[7] Definitions of the alternative spreads used in this paper are given in Table 1. The first ten of these spreads have been frequently used in the literature. The inclusion of the last spread, namely the mortgage spread, is motivated by the recent work of Hall (2011) and Walentin (2014).

We start our analysis by considering correlations between the spreads and the federal funds rate, ten-year Treasury bond rate, and 3- and 12-month-ahead industrial production growth. Table 2 shows the correlations both in the non-ZLB/conventional monetary policy period (1987:M9–2008:M11) and in the ZLB/unconventional monetary policy period (2008:M12–2014:M3). Several results stand out. First, as one might expect, the federal funds rate and the ten-year Treasury rate are positively correlated in the non-ZLB/conventional monetary policy period. Due to the fact that the federal funds rate has been fixed at or near zero since December 2008, the federal funds rate and the ten-year Treasury rate are uncorrelated in the ZLB/unconventional monetary policy period. Interestingly, the ten-year Treasury rate is positively correlated with 3- and 12-month-ahead industrial production growth both in the non-ZLB and ZLB environments. Thus, a higher long-term rate indicates higher future growth. On the other hand, the federal funds rate is generally uncorrelated with future industrial production growth. Second, and most importantly, the correlation coefficients presented in Table

[7]The Merrill Lynch U.S. High-Yield Master II index for the period 1986:M9—1996:M12 is taken from Mark Watson's webpage. During this period the high-yield index is the last daily observation of the month.

2 suggest that the behavior of the term spread has changed fundamentally since the beginning of the ZLB/unconventional monetary policy period. The term spreads (with the exception being the TS1y.3m spread based on two short-term rates) are negatively correlated with the federal funds rate but uncorrelated with the ten-year Treasury rate in the non-ZLB period. Thus, changes in the term spreads mostly reflect changes in the federal funds rate during this period. By contrast, in the ZLB period when the federal funds rate has been fixed at or near zero, the term spreads vary essentially one-for-one with the ten-year Treasury rate. The results indicate that the term spreads are significantly correlated with 12-month-ahead industrial production growth in both periods. However, correlations are much stronger in the later period. The term spreads are correlated with 3-month-ahead industrial production growth only in the ZLB period, probably because in the ZLB period term spreads fluctuate one-for-one with the ten-year Treasury rate, which itself is correlated with 3-month-ahead industrial production growth. The changes in the correlations suggest that the predictive power of the term spreads might have changed since the beginning of the ZLB/unconventional monetary policy period. Third, correlations between credit spreads and the federal funds rate and the ten-year Treasury rate have in some cases changed, but these changes are less dramatic. In general, credit spreads are significantly correlated with both 3- and 12-month-ahead industrial production growth.

Next, we evaluate whether the various interest rate spreads contain predictive power in a real-time out-of-sample forecasting exercise. We consider first the whole out-of-sample period running from 2003:M6 to 2014:M3. The results for this period are summarized in Table 3. The first row provides the root MSFE of the benchmark AR model.[8] For the subsequent rows, the first line reports the MSFE of a forecasting model using both the lagged values of industrial production growth and a candidate spread

[8] Forecast errors are calculated using the latest available data, i.e., the vintage of April 2014. The results are qualitatively similar if forecast errors are computed using the first available real-time vintages of data.

relative to the MSFE of the benchmark model. Values less (more) than one indicate that the model with a candidate spread has produced more (less) accurate forecasts than the benchmark, implying that the spread contains (does not contain) marginal predictive power. The p-value of the one-sided Giacomini and White (2006) test of equal unconditional predictive ability is reported in parantheses.[9]

The results reported in Table 3 suggest that the mortgage spread is a particularly informative leading indicator. The mortgage spread contains statistically significant predictive power for all four forecast horizons. Furthermore, its ability to forecast future industrial production growth is superior to all other spreads, regardless of the forecast horizon. The results also show that the difference between the Aaa corporate bond rate and the ten-year Treasury bond rate (i.e., the Aaa.10y spread) is a useful predictor of industrial production growth, although the null of equal accuracy cannot be rejected at conventional significance levels. The evidence for the rest of the credit spreads is mixed, but none of these spreads contains predictive power across all horizons. Various measures of the term spread also perform relatively poorly in the real-time forecasting exercise. Indeed, only in a few cases does inclusion of the term spread increase forecast accuracy. This result is interesting because the literature has identified the term spread as one of the most informative leading indicators (see, e.g., Stock and Watson, 2003).

The results reported in Table 3 focus on average predictive power over the whole out-of-sample period. However, the purpose of this study is to examine whether the ZLB and unconventional monetary policy affect the predictive content of different spreads. In order to analyze this question, we divide the out-of-sample period into two parts. The first period runs from 2003:M6 to 2008:M11 and it characterizes a period with normal monetary policy. The second period spans from 2008:M12 to 2014:M3. During this second period, short-term interest rates have been stuck at the ZLB and the Fed

[9] As discussed in Rossi (2013), different estimation window sizes may lead to different empirical results. We check the robustness of our results by considering three different rolling window sizes, namely 120, 150, and 180 observations. The results are similar for the three rolling windows, and hence we report the results for the rolling window of 150 observations only.

has used unconventional monetary policy. The results for these two subperiods are summarized in Table 4. The first row provides the root MSFE of the benchmark AR model in the two sample periods. In subsequent rows, the first line reports the MSFE of a forecasting model using a candidate spread relative to the MSFE of the benchmark model in the first subperiod; the second line reports the relative MSFE in the second period; and the third line reports the p-value of the Giacomini and White (2006) test of equal conditional predictive ability. This test is implemented by conditioning the relative predictive ability on an indicator taking the value of one when the short-term rate has been at the ZLB (2008:M12–2014:M3) and zero otherwise. Under the null hypothesis the model with the spread and the benchmark model have equal predictive ability regardless of whether the short-term rate is at the ZLB or not.

The results for the term spread models are particularly interesting. The results suggest that the predictive power of the term spread differs substantially in the two subperiods. In the first period, the relative MSFE values are above one, indicating that the term spreads do not contain predictive power in the non-ZLB/conventional monetary policy environment. However, later in the sample when the short-term rate has been fixed at the ZLB and the Fed has used unconventional policies, the term spreads have predictive power for future industrial production growth (the relative MSFE values are below one). The change in the predictive power is in most cases statistically significant and especially large when the forecast horizon is long (i.e., $h =$ 9 and 12). Thus, the results support the view that changes in monetary policy matter for the predictive power of the term spread (see, e.g., Estrella, 2005; Giacomini and Rossi, 2006).

On the other hand, the predictive ability of the mortgage spread seems to be unaffected by the change in monetary policy that took place in late 2008. The mortgage spread is the best leading indicator in both subperiods. It produces the most accurate real-time forecasts in each of the eight forecast horizon/sample period combinations considered. Interestingly, inclusion of the mortgage spread substantially improves forecast accuracy. For instance, the 9-month-ahead forecast based on the lagged values of industrial production growth and the mortgage spread have a relative MSFE of 0.43 in the second period, indicating a 57% improvement relative to the AR benchmark.

The effect of the ZLB restriction/unconventional monetary policy on the predictive content of the rest of the credit spreads is somewhat mixed. The difference between the Aaa corporate bond rate and the ten-year Treasury bond rate (the Aaa.10y spread) has predictive power for future industrial production only in the ZLB/unconventional monetary policy period. In general, however, the results indicate that credit spreads perform well in the first period but perform poorly in the second period. Although the differences in the relative MSFE values are large, the null of equal conditional predictive ability cannot be rejected at conventional significance levels. Note that some credit spreads (e.g., the Baa-Aaa corporate bond spread) perform poorly, whereas some credit spreads (e.g., the Aaa.10y andmMortgage spread) perform well in the ZLB/unconventional monetary policy period. Hence, no consensus on how the ZLB restriction and unconventional monetary policy affect the real-time predictive power of credit spreads emerges. This is probably due to the fact that credit spreads do not depend directly on the short-term rate and are thus only weakly correlated with the stance of monetary policy. Changes in the structure of the credit market are potentially more important for the predictive power of credit spreads than changes in monetary policy.

So far we have assumed that the forecasting ability of the interest rate spreads either remains constant over time (Table 3) or differs in the non-ZLB/conventional monetary policy and ZLB/unconventional monetary policy periods (Table 4). However, Giacomini and Rossi (2010) point out that the forecasting performance may be time varying. In such a case, average performance (either unconditional or conditional) over the whole out-of-sample period may hide important information and even lead to incorrect conclusions. Thus, we next consider the Giacomini and Rossi (2010) fluctuation test robust to instabilities. The fluctuation test is implemented by using a centered rolling window of 45 observations. We focus on the shortest 3-month-ahead forecast horizon because we want to maximize the number of out-of-sample observations for the ZLB/unconventional monetary policy period. Figure 2 reports both the fluctuation test statistic as well as the one-sided critical value at the 5% significance level (dashed horizontal line). Positive (negative) values of the fluctuation test indicate that the interest rate spread model has produced more (less) accurate forecasts than the AR benchmark. If the value of the fluctuation test exceeds the critical value, the null of equal local predictive ability at each point in time is rejected.

Inspection of Figure 2 reveals interesting details concerning the predictive ability of the term spread. At the beginning of the out-of-sample period, various term spread models typically produce larger MSFE values than the AR benchmark, implying that term spreads do not contain predictive power. Recently, however, the term spreads (with the exception being the TS1y.3m spread) have been informative leading indicators. For windows centered since early 2010, inclusion of the term spread improves forecast accuracy. Therefore, the fluctuation test suggests that the predictive power of the term spread has changed. The timing of this change corresponds closely to the beginning of the ZLB/unconventional monetary policy period.

The fluctuation test shows that the good performance of the mortgage spread reported in Tables 3 and 4 is not due to some specific subperiod. The forecasting model using both the lagged values of industrial production growth and the mortgage spread systematically produces more accurate real-time industrial production forecasts than the AR benchmark in the 2003–2014 period (the value of the fluctuation test is systematically positive). The null is rejected at the 5% significance level for all windows centered at 2007:M7 through 2010:M6, indicating that for those windows the mortgage spread contains statistically significant predictive power. Because the mortgage spread performs well over the whole out-of-sample period, the beginning of the ZLB/unconventional monetary policy environment has not changed its ability to forecast future industrial production growth.

The evidence for the paper-bill spread and the Baa.10y and Baa-Aaa corporate bond spreads is mixed. In general, these spreads do not add incremental predictive information in the real-time forecasting exercise. The results also suggest that the performance of the Aaa.10y spread and high-yield spreads as predictors of industrial production growth is somewhat episodic. For all windows centered before early 2007, inclusion of these spreads reduces forecast accuracy. However, later in the sample, the Aaa.10y spread and both high-yield spreads contain predictive information. Note that the predictive power of these credit spreads changed well before the short-term rate hit the ZLB and the Fed started to use unconventional monetary policy. Generally speaking, the fluctuation test does not show systematic deterioration/improvement in the forecasting ability of credit spreads since the beginning of the ZLB/unconventional monetary policy environment. Hence, the predictive power of credit spreads seems to be unaffected by the ZLB and unconventional monetary policy.

All in all, the results indicate that the predictive power of the term spread is unstable over time. The term spread has no predictive power for U.S. industrial production growth at the beginning of the out-of-sample period. Recently, however, the term spread has been a useful leading indicator. The literature has indicated that changes in monetary policy regimes are important for the predictive content of the term spread (see, e.g., Giacomini and Rossi, 2006). Therefore, the onset of the ZLB/unconventional monetary policy period provides a potential explanation for the observed change in predictive ability. The ZLB on nominal interest rates and unconventional monetary policy affect the behavior of the term spread. Therefore, it is not surprising that the timing of the change in the predictive content seems to correspond closely to the beginning of the ZLB/unconventional monetary policy period.

In general, the track record of credit spreads as indicators of U.S. industrial production growth is not good. The results show that most credit spreads contain predictive power only episodically. The predictive content of credit spreads seems to be unaffected by the ZLB and unconventional monetary policy. This finding is not surprising. Credit spreads contain predictive power primarily because they indicate changes in the supply of credit and expectations of default (Ng and Wright, 2013). Therefore, it is natural to interpret changes in the predictive power as being driven by other reasons than the ZLB and unconventional monetary policy. The real-time forecasting exercise suggests that the mortgage spread is a particularly informative leading indicator. The mortgage spread is a robust predictor of future economic activity across a variety of sample periods and forecast horizons. Furthermore, the mortgage spread systematically produces more accurate forecasts than the other spreads.

4. Conclusions

This paper analyzed the leading indicator properties of various interest rate spreads when the short-term rate has been fixed at the ZLB and the Fed has used unconventional monetary policy. The re-examination is motivated by the fact that the ZLB on nominal interest rates and unconventional monetary policy affect the behavior of the term spread. Our results suggest that the predictive content of the term spread in the ZLB/unconventional monetary policy period differs from that in the non-ZLB/conventional monetary policy period. In normal times, the term spread is not informative about future industrial production growth. However, when the short-term rate is fixed at the zero level and the Fed uses unconventional monetary policy, the term spread performs better and contains predictive power. The results are consistent with the view that changes in the monetary policy regime affect the predictive power of the term spread.

Most credit spreads contain predictive power only episodically in our real-time forecasting exercise. The instability in predictive relationships highlights the burdens associated with using credit spreads as business cycle indicators; predictors that perform well in one period may work poorly in another. Although the predictive power of credit spreads fluctuates over time, the ability of credit spreads to signal future industrial production growth seems to be unaffected by the beginning of the ZLB and unconventional monetary policy era.

Our results indicate that the mortgage spread is a particularly useful leading indicator for U.S. industrial production growth. It outperforms the term spread and a set of widely used credit spreads in our real-time forecasting exercise regardless of the forecast horizon and sample period under investigation. Importantly, we find that the mortgage spread contains substantial predictive power both in the non-ZLB/conventional monetary policy and ZLB/unconventional monetary policy periods. Thus, the results suggest that the ZLB and unconventional monetary policy do not change the predictive content of the mortgage spread.

Although the mortgage spread is a robust predictor, our sample period is relatively short, running from 2003 to 2014. It would be interesting to examine the predictive power of the mortgage spread using a longer sample period from the 1970s to the present. Furthermore, one would like to know whether the mortgage spread has predictive power for other measures of economic activity, such as GDP and consumption. We leave these issues for future research.

References

Bernanke, B. S. (1990). On the predictive power of interest rates and interest rate spreads. *New England Economic Review*, 51-68.

Bernanke, B. S., & Blinder, A. S. (1992). The federal funds rate and the channels of monetary transmission. *American Economic Review*, 82, 901-921.

Bernanke, B. S., Reinhart, V. R., & Sack, B. P. (2004). Monetary policy alternatives at the zero bound: an empirical assessment. *Brookings Papers on Economic Activity*, 1-78.

Bordo, M. D., & Haubrich, J. G. (2008). The yield curve as a predictor of growth: long-run evidence, 1875–1997. *Review of Economics and Statistics*, 90, 182-185.

Elliott, G., & Timmermann, A. (2008). Economic forecasting. *Journal of Economic Literature*, 46, 3-56.

Chung, H., Laforte, J-P., Reifschneider, D., & Williams, J. C. (2012). Have we underestimated the likelihood and severity of zero lower bound events? *Journal of Money, Credit, and Banking*, 44, 47-82.

Estrella, A., Rodrigues, A. P., & Schich, S. (2003). How stable is the predictive power of the yield curve? evidence from Germany and the United States. *Review of Economics and Statistics*, 85, 629-644.

Estrella, A. (2005). Why does the yield curve predict output and inflation? *Economic Journal*, 115, 722-744.

Faust, J., Gilchrist, S., Wright, J. H., & Zakrajšek, E. (2013). Credit spreads as predictors of real-time economic activity: a Bayesian model-averaging approach. *Review of Economics and Statistics*, 95, 1501-1519.

Friedman, B. M., & Kuttner, K. N. (1992). Money, income, prices and interest rates. *American Economic Review*, 82, 472-492.

Friedman, B. M., & Kuttner, K. N. (1998). Indicator properties of the paper-bill spread: lessons from recent experience. *Review of Economics and Statistics*, 80, 34-44.

Gertler, M., & Lown, C. S. (1999). The information in the high-yield bond spread for the business cycle: evidence and some implications. *Oxford Review of Economic Policy*, 15, 132-150.

Giacomini, R., & Rossi, B. (2006). How stable is the forecasting performance of the yield curve for output growth? *Oxford Bulletin of Economics and Statistics*, 68, 783-795.

Giacomini, R., & Rossi, B. (2010). Forecast comparisons in unstable environments. *Journal of Applied Econometrics*, 25, 595-620.

Giacomini, R., & White, H. (2006). Tests of conditional predictive ability. *Econometrica*, 74, 1545-1578.

Gilchrist, S., & Zakrajšek, E. (2012). Credit spreads and business cycle fluctuations. *American Economic Review*, 102, 1692-1720.

Gilchrist, S., Yankov, V., & Zakrajšek, E. (2009). Credit market shocks and economic fluctuations: evidence from corporate bond and stock markets. *Journal of Monetary Economics*, 56, 471-493.

Hall, R. E. (2011). The long slump. *American Economic Review*, 101, 431-469.

Krippner, L. (2013). Measuring the stance of monetary policy in conventional and unconventional environments. *Working Paper, Centre for Applied Macroeconomic Analysis* (forthcoming).

Mody, A., & Taylor, M. P. (2003). The high-yield spread as a predictor of real economic activity: evidence of a financial accelerator for the United States. *IMF Staff Papers*, 50, 373-402.

Newey, W. K., & West, K. D. (1987). A simple, positive semidefinite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica*, 55, 703-708.

Ng, S., & Wright, J. H. (2013). Facts and challenges from the Great Recession for forecasting and macroeconomic modeling. *Journal of Economic Literature*, 51, 1120-1154.

Rossi, B. (2013). Advances in forecasting under instability. In G. Elliott, & A. Timmermann (Eds), *Handbook of Economic Forecasting*, vol. 2, North-Holland, Amsterdam. 1203-1324.

Stock, J. H., & Watson, M. W. (2003). Forecasting output and inflation: the role of asset prices. *Journal of Economic Literature*, 41, 788-829.

Swanson, E. T., & Williams, J. C. (2014). Measuring the effect of the zero lower bound on medium- and longer-term interest rates. *American Economic Review* (forthcoming).

Walentin, K. (2014). Business cycle implications of mortgage spreads. *Sveriges Riksbank Working Paper Series*, No. 275.

Tables

TABLE 1
Definitions of the variables

Series label	*Definition*
TS10y.3m	Treasury bond (10 years) — Treasury bill (3 months)
TS10y.1y	Treasury bond (10 years) — Treasury bill (1 year)
TS10y.Ffs	Treasury bond (10 years) — Federal funds rate (overnight)
TS1y.3m	Treasury bill (1 year) — Treasury bill (3 months)
Paper.bill	Commercial paper (3 months) — Treasury bill (3 months)
Aaa.10y	Long-term corporate bond (Aaa rating) — Treasury bond (10 years)
Baa.10y	Long-term corporate bond (Baa rating) — Treasury bond (10 years)
Baa.Aaa	Long-term corporate bond (Baa rating) — long-term corporate bond (Aaa rating)
Hy.10y	High-yield bond — Treasury bond (10 years)
Hy.Aaa	High-yield bond — long-term corporate bond (Aaa rating)
Mortgage	Mortgage rate (30 years) — Treasury bond (10 years)

Table 2

Correlations between the spreads and the federal funds rate, the 10-year Treasury rate, and industrial production growth

	Fed funds rate		10-year Treasury		IP_{t+3}		IP_{t+12}	
	pre ZLB	ZLB	pre ZLB	ZLB	pre ZLB	ZLB	pre ZLB	ZLB
Fed funds rate	1.00***	1.00***	0.79***	0.19	0.10	-0.26**	0.04	-0.05
10-year Treasury	0.79***	0.19	1.00***	1.00***	0.22***	0.28**	0.24***	0.54***
TS10y.3m	-0.55***	0.12	0.06	1.00***	0.07	0.30**	0.16***	0.54***
TS10y.1y	-0.66***	0.06	-0.10*	0.98***	0.01	0.38***	0.12**	0.55***
TS10y.Ffs	-0.66***	0.13	-0.06	1.00***	0.10*	0.30**	0.22***	0.54***
TS1y.3m	0.15***	0.41***	0.54***	0.60***	0.21***	-0.25**	0.21***	0.26*
Paper.bill	0.43***	0.21*	0.33***	0.02	-0.34***	-0.72***	-0.44***	-0.52***
Aaa.10y	-0.58***	0.16	-0.59***	-0.33***	-0.39***	-0.74***	-0.32***	-0.35***
Baa.10y	-0.50***	0.36***	-0.46***	-0.10	-0.52***	-0.73***	-0.43***	-0.28**
Baa.Aaa	-0.16***	0.41***	-0.07	0.00	-0.49***	-0.67***	-0.41***	-0.23*
Hy.10y	-0.08	0.37***	-0.05	0.07	-0.60***	-0.66***	-0.46***	-0.19
Hy.Aaa	0.06	0.38***	0.08	0.10	-0.59***	-0.64***	-0.44***	-0.17
Mortgage	-0.13**	0.01	-0.34***	-0.53***	-0.47***	-0.72***	-0.53***	-0.59***

Notes: Sample period: Monthly data from 1987:M9 to 2014:M3. The pre ZLB period runs from 1987:M9 to 2008:M11 and the ZLB period spans from 2008:M12 to 2014:M3. *, **, *** denote statistically significant at 10, 5, 1% levels, respectively.

Table 3

Out-of-sample mean squared forecast errors

Spread	h=3	h=6	h=9	h=12
Uni.	6.55	6.53	6.28	5.95
TS10y.3m	1.03	1.02	1.09	1.02
	(0.83)	(0.69)	(0.79)	(0.62)
TS10y.1y	1.00	1.00	0.97	0.99
	(0.50)	(0.47)	(0.16)	(0.47)
TS10y.Ffs	1.01	1.08	1.09	1.00
	(0.68)	(0.78)	(0.72)	(0.49)
TS1y.3m	1.18	1.16	1.09	1.02
	(0.94)	(0.84)	(0.75)	(0.57)
Paper.bill	0.96	1.07	1.01	1.01
	(0.35)	(0.64)	(0.53)	(0.54)
Aaa.10y	0.93	0.92	0.94	0.98
	(0.14)	(0.15)	(0.24)	(0.41)
Baa.10y	0.96	1.10	1.02	0.89
	(0.39)	(0.67)	(0.58)	(0.17)
Baa.Aaa	0.95	1.15	1.24	1.17
	(0.33)	(0.73)	(0.78)	(0.74)
Hy.10y	0.94	1.13	1.16	1.09
	(0.31)	(0.73)	(0.90)	(0.88)
Hy.Aaa	0.97	1.22	1.22	1.11
	(0.39)	(0.81)	(0.90)	(0.92)
Mortgage	0.69	0.61	0.62	0.67
	(0.01)	(0.02)	(0.04)	(0.05)

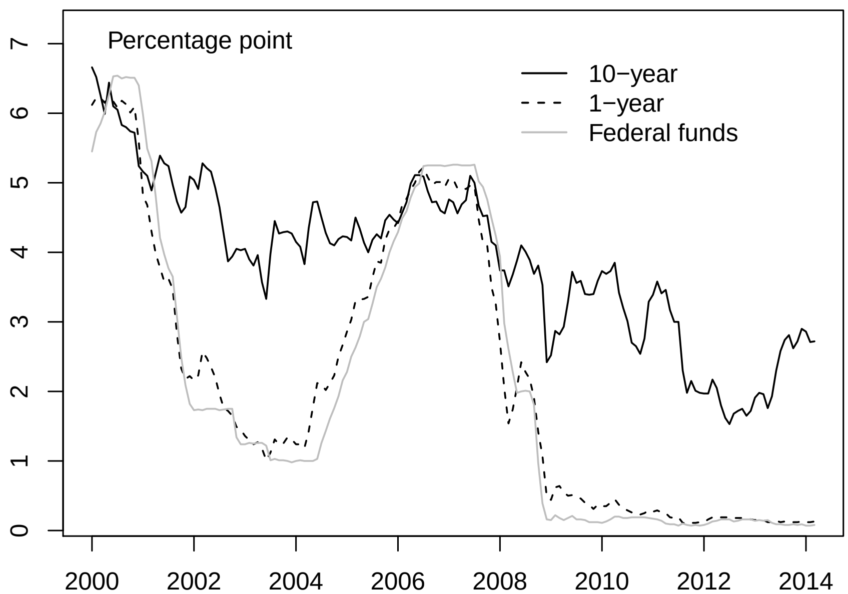
Notes: Sample period: Monthly data from 2003:M6 to 2014:M3. The first row shows the root mean squared forecast error for the univariate autoregression. In subsequent rows, the first line reports the ratio of the MSFE of a candidate model relative to the MSFE of the benchmark model; the p-value of the one-sided Giacomini and White (2006) test of equal unconditional predictive ability is reported in parentheses. The truncation lag for the Newey-West (1987) HAC estimator is h-1, where h is the forecast horizon.

Table 4
Tests of equal conditional predictive ability

Spread	h=3	h=6	h=9	h=12
Uni.	6.89	7.12	7.11	6.85
	6.17	5.79	5.11	4.57
TS10y.3m	1.08	1.07	1.19	1.12
	0.96	0.92	0.87	0.76
	(0.10)	(0.03)	(0.05)	(0.03)
TS10y.1y	1.03	1.03	1.02	1.06
	0.96	0.95	0.87	0.80
	(0.27)	(0.21)	(0.13)	(0.04)
TS10y.Ffs	1.08	1.21	1.23	1.11
	0.93	0.87	0.75	0.70
	(0.04)	(0.04)	(0.04)	(0.05)
TS1y.3m	1.30	1.29	1.19	1.11
	1.03	0.94	0.86	0.75
	(0.30)	(0.27)	(0.40)	(0.57)
Paper.bill	0.92	0.89	0.88	0.92
	1.02	1.37	1.30	1.27
	(0.33)	(0.38)	(0.41)	(0.42)
Aaa.10y	1.05	0.99	1.04	1.09
	0.77	0.81	0.71	0.66
	(0.11)	(0.27)	(0.32)	(0.09)
Baa.10y	0.88	0.84	0.89	0.93
	1.08	1.55	1.35	0.77
	(0.50)	(0.36)	(0.47)	(0.64)
Baa.Aaa	0.84	0.84	0.85	0.86
	1.10	1.68	2.14	2.03
	(0.23)	(0.21)	(0.22)	(0.26)
Hy.10y	0.91	0.92	1.04	1.11
	0.98	1.50	1.44	1.04
	(0.86)	(0.60)	(0.41)	(0.34)
Hy.Aaa	0.94	0.94	1.03	1.08
	1.01	1.70	1.64	1.19
	(0.92)	(0.55)	(0.39)	(0.35)
Mortgage	0.76	0.70	0.70	0.73
	0.59	0.47	0.43	0.51
	(0.04)	(0.13)	(0.22)	(0.25)

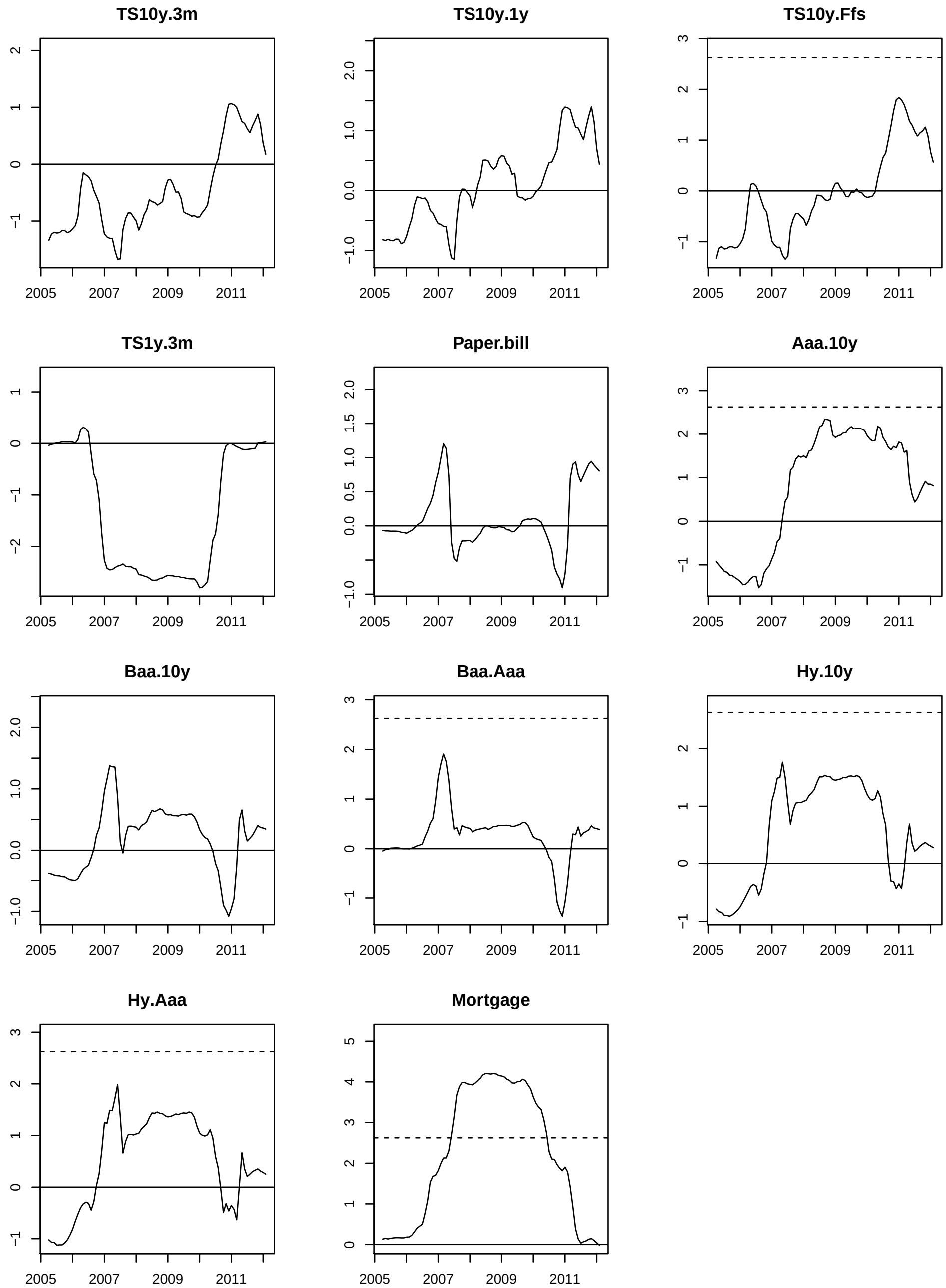
Notes: The first period runs from 2003:M6 to 2008:M11 and the second from 2008:M12 to 2014:M3. The first row provides the root MSFE for the univariate autoregression in the two sample periods. In subsequent rows, the first line reports the MSFE of a candidate model relative to the MSFE of the benchmark model in the first period; the second line reports the relative MSFE in the second period; the p-value of the Giacomini and White (2006) test of equal conditional predictive ability is reported in parentheses. The test function is $h_t = (1, ZLB_t)'$, where ZLB_t is a dummy variable taking the value of one when the ZLB restriction is binding (2008:M12—2014:M3) and zero otherwise.

Figure 1. Treasury rates since 2000



Notes: Sample period 2000:M1—2014:M3. The data are extracted from the Federal Reserve Economic Data (FRED) (Federal Reserve Bank of St. Louis).

Figure 2. Fluctuation test for equal out-of-sample predictability (h = 3 months)



Notes: The figure plots the Giacomini and Rossi (2010) fluctuation test based on sequences of the Giacomini and White (2006) (GW) unconditional test statistics. The fluctuation test is implemented by using a centered rolling window of 45 observations (i.e., μ = m/P is approximately 0.4, where m is the size of the rolling window of the GW statistics and P is the number of out-of-sample observations). The sample period spans from 2003:M6 to 2014:M3. Positive (negative) values indicate that the interest rate spread model has produced more (less) accurate forecasts than the benchmark. The dashed line represents the critical value at the 5% significance level. If the fluctuation test statistic exceeds the critical value (2.770), the null that the two models have equal predictive ability at each point in time is rejected.